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January 31, 1997

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

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William F. Caton
Acting Secretary
Federal Communications Commission
Mail Stop 1170
1919 M Street, N.W., Room 222
Washington, DC 20554

Re: IB Docket No. 95-91, GEN Docket No. 90-357, RM No. 86-10

Dear Mr. Caton:

Enclosed is a response prepared by Mr. Robert D. Briskman, President, Satellite CD Radio, Inc. (biography attached), regarding the recent submission of the Consumer Electronics Manufacturers Association (CEMA).

As Mr. Briskman's response shows, satellite DARS can provide good service at S-Band, there is little meaningful difference between S-Band and L-Band for this service, and L-Band cannot be used for SDARS because it is already used for critical government services.

Very truly yours,

Michael Yourshaw

cc: Chairman Hundt, Commissioners Quello, Chong, and Ness, Richard M. Smith, Donald H. Gips

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## CD Radio Response to CEMA

CEMA's conclusion recommending "immediate FCC consideration of other spectrum options such as L-Band (1452-1492 MHz), UHF or VHF" is INCORRECT

- CEMA confuses needs for terrestrial DARS (TDARS) and satellite DARS (SDARS).
- The testing and reporting is in dispute (Refs. 1 & 5)
- L-Band (1452-1492 MHz) is used for critical government services in the United States which cannot share with TDARS or SDARS (Ref. 1)
- S-Band is suitable for SDARS despite "CEMA's testing conclusively finds that S-Band is unsuitable ..."
    - Only one system was tested by CEMA
    - System tested had no diversity (spatial, frequency or time) and operated at low elevation angle from a medium powered satellite (Ref. 2)
    - CEMA test data show that the need for gap filling transmitters in urban areas is modest rather than "thousands"
- Broadcasters believe TDARS should be IBOC (Ref. 3) for compelling market and migration reasons
    - No broadcaster proponent exists for any non-IBOC system
    - New USADR IBOC system under development (Ref. 4). Other IBOC possibilities exist
- Receiver manufacturers represented by CEMA are frustrated by lack of TDARS/SDARS progress, especially in contrast with other countries
- Conclusion:
    - A new frequency band is not required
    - SDARS implementation at S-Band and IBOC development should be expedited

CD RADIO

# ROBERT D. BRISKMAN

## Biography

Robert D. Briskman is Chief Technical Officer of CD Radio Inc. and President of its Systems Group. He has been involved with communication satellite systems since their inception. Mr. Briskman is responsible for the development, implementation and management of CD Radio's satellite broadcast distribution system. His technology development responsibility includes design of low cost satellite receiving terminals for automobiles and of direct broadcast sound programming and operational facilities.

Prior to CD Radio, Mr. Briskman was with the Geostar Corporation from 1986-1991. He was responsible at Geostar for the development, design, implementation and operation of the Radio Determination Satellite Service provided by Geostar which allows positioning and message communications between mobile users nationwide and their dispatch centers. Mr. Briskman directed the construction of Geostar's space segment, the control and operations center and the development of the mobile terminals used on land, sea and airborne vehicles built by the SONY, HUGHES Network Systems and KENWOOD Corporations. He was responsible for the development of a miniaturized handheld transceiver by Motorola which was the world's smallest satellite earth terminal. Mr. Briskman served as Senior Vice President, Engineering and Operations.

Mr. Briskman was employed by the Communications Satellite Corporation (COMSAT) in January 1964, and was responsible initially for satellite command and control activities, including those involved with the launching of INTELSAT I (Early Bird). He was later a Department Manager in the Transmission Systems Division, where he was involved with the development and implementation of the INTELSAT global communications system. Among his efforts, early work in demand assigned single carrier per channel, radio frequency interference minimization and terrestrial interconnection was accomplished. Mr. Briskman was responsible from 1967-1973 for the technical planning involved with the provision of domestic communications services via satellites, including AT&T's satellite systems.

CD RADIO

Mr. Briskman joined COMSAT General Corporation on its founding in 1973 and was Assistant Vice President, Space and Information Systems. He was responsible for the COMSTAR satellite system, the development of earth resource and information systems, and the implementation of the first remote satellite data collection system in conjunction with the United States Geological Survey and Telesat Canada. He directed the construction of the Southbury and Santa Paula earth stations which were used for command and control of both MARISAT and COMSTAR satellites and for shore communications to the Atlantic and Pacific MARISAT satellites. Mr. Briskman joined Satellite Business Systems in mid-1977 where he was responsible for the Pre-Operational Program which provided voice and data communications services to many IBM facilities in the United States using the first demand-assigned, time division multiple access system ever placed in commercial operations.

Mr. Briskman returned to COMSAT General in 1980 where he was responsible as Vice President, Systems Implementation for the engineering of satellites, earth stations and communications technical facilities of COMSAT General and of clients, both within and external to COMSAT. His organization provided a complete range of technical services nationally and internationally, including those involved with software, spectrum engineering and teleconferencing. Mr. Briskman was responsible for the PALAPA (Indonesia's domestic satellite system), MORELOS (Mexico's domestic satellite system), ARABSAT and ITALSAT programs as well as for providing support to the INMARSAT, INTELSAT, STC (Direct broadcast), TELSTAR-3, ALASCOM, SATCOL, UNISAT, INTELMET, NORDSAT, CHINASAT AND CAMEROON programs.

Prior to COMSAT, Mr. Briskman joined the National Aeronautics and Space Administration (NASA) during its founding in 1959. At NASA, Mr. Briskman was Chief of Program Support for the Office of Tracking and Data Acquisition. He was involved with the development of ground instrumentation for such projects as APOLLO, GEMINI, RANGER, MARINER, and ECHO. Mr. Briskman received the APOLLO Achievement Award from NASA for the design and implementation of the Unified S-Band System. Before NASA, he was employed by IBM in 1954 and worked on the design of asynchronous buffer systems. After two years of military service as an Electronic Countermeasures Analyst Officer, for which he was awarded the Army Commendation Medal, Mr. Briskman was employed by the Army Security Agency. He was engaged in communications systems development and analysis.

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Mr. Briskman is a Fellow and past Secretary-Treasurer, Vice President for Technical Activities and Director of the Institute of Electrical and Electronics Engineers (IEEE). He has been President of the Aerospace and Electronics Systems Society, Director of the National Telecommunications Conference, Chairman of the EASCON Board of Directors, and Chairman of the IEEE Standards Board. Mr. Briskman has authored over fifty technical papers, holds several United States and foreign patents, served on the Industry Advisory Council to NASA, and is a licensed professional engineer. He is a Fellow of the AIAA and the Washington Academy of Science, past President of the Washington Society of Engineers, and a member of IAA, AFCEA and the Old Crows. He is also a recipient of the IEEE Centennial Medal. Mr. Briskman holds a B.S.E. degree from Princeton University and a M.S.E.E. degree from the University of Maryland.

8/14/96

Reference 1

Documents
Radiocommunications
Study Groups

USTG 8-3/11 (Rev. 1)
WP 10-11S/US-9 (Rev. 1)
USWP 8B/
USWP 8D/9 (Rev. 1)
USTG 2-2/4 (Rev. 1)
17 October 1994
Original: English

**United States of America**

**Revision of 8B/TEMP/26 (Rev. 1)**

# PRELIMINARY DRAFT NEW RECOMMENDATION

## COORDINATION THRESHOLDS AND TECHNIQUES FOR THE PROTECTION OF MOBILE AERONAUTICAL TELEMETRY SYSTEMS FROM GEOSTATIONARY SATELLITE EMISSIONS IN THE BAND 1 452 - 1 525 MHz

**(Resolutions 528, 46 and WARC-92)**

**(Question 62/8)**

THE ITU/R

**CONSIDERING**

(a) that in Region 2 and some Region 1 and 3 countries the band 1 452-1 525 MHz is specifically allocated to the Aeronautical Mobile Telemetry Service on a primary basis by No. 723, No. 723B, and 722C.

(b) that at WARC-92 the band 1 452-1 492 MHz was allocated to the Broadcasting Satellite Service and the Broadcasting Service, subject to the provision of 722A, 722B, and 722C.

(c) that at WARC-92 the band 1 492-1 525 MHz was allocated to the Mobile Satellite Service (space-to-Earth) in Region 2 taking account of the provisions of 723C.

(d) that the aeronautical mobile telemetry service requires interference protection from the services identified in (b) and (c) in the indicated frequency bands.

(e) that there are no coordination thresholds that apply with respect to protection of the Aeronautical Mobile Telemetry service in these bands.

(f) that coordination is required under Resolutions 46 and 528.

(g) that Resolutions 528 and 213 invite the RS to conduct the necessary studies prior to the next (appropriate) World Radio Conference (WRC).

**RECOMMENDS**

1. that the threshold for determining the need for coordination between administrations using geostationary satellites in the broadcasting-satellite (DSB)* or the mobile-satellite service and administrations using the aeronautical-mobile service (telemetry) in the 1 452-1 525 MHz band is determined by the following:

* DSB (digital sound broadcasting) refers to digital audio broadcasting as per Nos. 722A and 750B.

- **For geostationary satellites visible to any aeronautical telemetry receiving station, the threshold corresponds to a power flux density at the telemetry receiving station in any 4 kHz band for all methods of modulation of:**

| | |
|---|---|
| **-181.0** | **dB(W/m$^2$) for $0 \leq \alpha \leq 4°$** |
| **-193.0 + 20 log$\alpha$** | **dB(W/m$^2$) for $4° < \alpha \leq 20°$** |
| **-213.3 + 35.6 log$\alpha$** | **dB(W/m$^2$) for $20° < \alpha \leq 60°$** |
| **-150.0** | **dB(W/m$^2$) for $60° < \alpha \leq 90°$** |

**where $\alpha$ is the angle of arrival (degrees above the horizontal plane).**

**2.　that the calculation methods and coordination techniques given in Annex 1 should be used, as applicable, for determining interference to the aeronautical Mobile Telemetry Service during coordination.**

# ANNEX 1

## COORDINATION THRESHOLDS AND TECHNIQUES FOR THE PROTECTION OF MOBILE AERONAUTICAL TELEMETRY SYSTEMS FROM GEOSTATIONARY SATELLITE EMISSIONS IN THE BAND 1 452 - 1 525 MHz

## 1.0 INTRODUCTION

At the WARC-92, the band 1 452 - 1 492 MHz was allocated to the broadcasting-satellite service and the broadcasting service and, under the provisions of 722A is limited to digital audio and subject to Resolution 528. The band 1 492 - 1 525 MHz was allocated to the mobile-satellite service (space-to-Earth) in Region 2, subject to the provisions of No. 723C. A coordination threshold was provisionally applied which corresponds to the power flux density (pfd) limits given in No. 2566 with respect to terrestrial services, except for the situation referred to in No. 723. For this case, the procedures of Resolution 46 apply.

Under Radio Regulations 723 and 723B, aeronautical-mobile (telemetry) has a primary allocation in a number of nations. No pfd limits apply to the use of these bands for this purpose, and coordination is required in these cases under Resolutions 46 and 528. Resolutions 528 and 213 invite the CCIR to conduct the necessary studies prior to the next (appropriate) World Radio Conference (WRC).

The analyses and results given in the following sections of this document are for the purpose of developing coordination thresholds, methods for calculating interference, and techniques for reducing interference to aeronautical-mobile telemetry systems (AMT).

## 2.0 TELEMETRY SYSTEM CHARACTERISTICS

### 2.1 General

General system characteristics are given in Reference (1) and are as follows. Aeronautical telemetry and telecommand operations are used for flight testing of manned and unmanned aerospace vehicles. Vehicles are tested to their design limits, thus making safety of flight dependent on the reliability of information received on a real-time basis. When being tested to design limits, signal strength loss can exceed 30 dB due to nulls in the aircraft antenna pattern caused by aircraft attitude changes.

| | |
|---|---|
| Required C/N | 9-15 dB |
| Transmitter Power | 2-25 W |
| Modulation Type | PCM/FM |
| Transmission Path Length | up to 320 km |
| Receiving System Noise Temp. | 200-500 K |
| Receiving Antenna Gain | 20-41 dB |

Receive antenna first side lobe levels for two antennas

| | |
|---|---|
| 10 m (diameter) | 20 dBi (antenna gain)<br>2.4° (from center) |
| 2.44 m (diameter) | 7-14 dBi (antenna gain)<br>10° (from center) |

A number of antenna diameters are employed between the 20-41 dB limits. Left-hand and right-hand circular, as well as linear polarizations, are used.

Channel assignments are made in 1-MHz increments. Typical emissions are 1, 3, and 5 MHz in bandwidth with wider assignments made for video and other complex measurements.

The maximum air space for a telemetry receiving site is defined as a cylinder with a horizontal radius of 320 km around the site, with the lower bound determined by visibility and the upper bound determined by an altitude of 20 km. The minimum air space for a particular mission is defined as a vertical cylinder with a radius of 20 km within the maximum air space with the same lower and upper bounds as for the maximum air space.

Continuous RF tracking is employed using both monopulse and conical scan techniques.

There is no international agreement on required performance objectives for AMT. However, administrations may agree to mutually acceptable protection in bi-lateral coordination.

## 2.2 Telemetry Receiving Antennas

Two antenna diameters are given a 2.44-meter and a 10-meter diameter. Figure 1 shows measured gain values for three 2.44-meter antennas. Since these antennas track a moving vehicle so that the antenna gain toward a geostationary satellite is variable, there is a sidelobe and backlobe gain which is excessed or not exceeded 50 percent of the time. The following composite pattern is developed on this basis for antenna gains from 29 dB to 41.2 dB.

$$G(\theta) = 41.2 + 20 \log (\sin 1.952\theta / 1.952\theta) \text{ (dBi)} \quad ; 0° \le \theta \le 0.94° \qquad (1a)$$

$$G(\theta) = 35.1 - 20 \log \theta \text{ (dBi)} \quad ; 0.94° < \theta \le 3.82° \qquad (1b)$$

$$G(\theta) = 29 + 20 \log (\sin 0.479\theta / 0.479\theta) \text{ (dBi)} \quad ; 3.82° < \theta \le 5.61 \qquad (1c)$$

$$G(\theta) = 27.27 - 18.75 \log \theta \text{ (dBi)} \quad ; 5.61° < \theta \le 12.16° \qquad (1d)$$

$$G(\theta) = 34.05 - 25 \log \theta \text{ (dBi)} \quad ; 12.16° < \theta \le 48° \qquad (1e)$$

$$G(\theta) = -8 \text{ (dBi)} \quad ; 48° < \theta \le 180° \qquad (1f)$$

## 2.3 Telemetry Transmitting Antennas

The telemetry transmitting antennas are mounted on airborne vehicles and, ideally, would be isotropic radiators to cover all possible radiation angles toward the telemetry receiving station. However, in practice, multiple reflections and blockage from the airborne vehicles cause large variations in the gain pattern. Multiple reflections generally result in a Rayleigh fading distribution, and measured gain functions have shown that this is approximately the case as shown in Figure 2. Using Figure 2 for a near worst case, including propagation effects, the probability (portion of time) ($P_1$) that a given gain ($G_1$) is not exceeded can be expressed as:

$$P_1 (G \le G_1) = [1 - e^{-3.46 G_1}]^{1.25} \text{ (numerical)} \qquad (2)$$

Distributions corresponding to an exponent of ($-5G_1$) are observed.

The received carrier-to-noise ratio (C/N) and carrier power (C) at output of the telemetry receiving antenna are proportional to this function.

# 3.0 INTERFERENCE FROM GEOSTATIONARY SATELLITES

## 3.1 Time-Gain Function of Interference

If it is assumed that the telemetry antenna may be pointed at any point on its hemisphere of visibility, the cumulative probability ($P_2$) that a satellite at geostationary altitude is within a radius of ($\theta$), as viewed from the telemetry receiving station, is:

$$P_2 = (1 - \cos \theta) \quad ; 0 \le \theta \le \pi/2 \qquad (3)$$

The ($\theta$) in equation (1) is the same as in equation (3). Thus, by combining equations (1) with (3), functions can be developed which relate the probability (portion of time) that the telemetry receiving antenna gain (G) toward the satellite is equal to or greater than a given value ($G_2$) as shown in Figure 3.

The received interference-to-noise ratio (I/N) and the interference power (I) are proportional to the functions shown in Figure 3.

In the case of geostationary satellite, the angle-of-arrival of interference at a telemetry receiving station is fixed. The only randomness involved is the telemetry receiving antenna pointing variations. Testing of airborne vehicles is often restricted to areas over water or uninhabited land in order to preclude danger to life or property in case of catastrophic failure of the vehicle being tested, thereby limiting the azimuth angles for these tests. There are also minimum limits on the azimuth and elevation pointing angle variations of the telemetry receiving antenna that are defined by the minimum air space in Section 2.1.

### 3.2 C/I Analysis

Since equation (2) is proportional to carrier power (C) and the functions in Figure 3 are proportional to interference power (I), the probability of C/I can be determined and is proportional to:

$$P\left((C/I) \geq (C/I)_c\right) \propto \left[\left(P_1\,(G' \leq G_1)\right) / \left(P_2\,(G'' \leq G_2)\right)\right] \qquad (4)$$

where $(C/I)_c$ is a chosen value.

The brackets indicate the joint, cumulative probability function. The (C) and (I) functions are independent since they result from independent sources. The indicated integrations were performed for various limited ranges of $(P_2)$ which, in turn, corresponds to limited steradian areas (S) when the satellite is within the minimum airspace defined in Section 2.1. These integrations may be expressed as:

$$P_3\,(\Delta G \geq G_2/G_1) = \left[\left(P_2\,(G'' \geq G_2)\right) / \left(P_1\,(G' \leq G_1)\right)\right] \qquad (5)$$

The (C/I) in equation (4) is normally expressed in relation to (C/N), and since loss of availability is the prime concern, it is expressed in relation to the threshold $(C/N)_T$ as follows:

$$(C/I) \geq (C/N)_T\,(P_4/P_3) \qquad (6)$$

where $(P_4)$ is the probability associated with $(C/N)_T$ and is set equal to $P(\Delta G)$ and $P_3$ is the probability associated with (C/I). The ratio $(P_3/P_4)$ is analogous and numerically equal to (I/N) criteria. The allowable non-availability (P) is based on (C/(N+I)) so that $P(\Delta G) = P\text{-}P_3$ which results in:

$$P(\Delta G) = P/(I/N+1) \qquad (7)$$

It is now necessary to relate $(\Delta G)$ to pfd. First, a pfd is determined when the telemetry antenna is directed toward the satellite:

$$\text{pfd} \leq \frac{kTB\,(I/N)}{(\lambda^2/4\pi)\,G_o}\ (\text{watts/m}^2/\text{B}) \qquad (8)$$

where: $k$ = Boltzmann's Constant
$B$ = Bandwidth-Hz
$T$ = Noise Temperature-K°
$G_o$ = 13183 (41.2 dB).

This pfd is associated with a $(\Delta G)_m$ at a $P(\Delta G)$. At $(G_o)$, only C is variable and thus, (C/I) is given by equation (2). The $(\Delta G)_m$ function is closely approximated by:

$$(\Delta G)_m = 45000/P(\Delta G)^{1.25} \qquad (9)$$

The pfd from equation (8) can be increased by $(\Delta G)m/(\Delta G)$. Thus:

$$pfd \leq \frac{kTB\,(I/N)}{G_o\,(\lambda^2/4\pi)} \cdot \frac{(\Delta G)_m}{(\Delta G)}\ ;\ P(\Delta G)_m = P(\Delta G)\ (\text{watts/m}^2/B) \tag{10}$$

## 3.3 Impact on Telemetry Link Design

Analyses show that the value of (P), the telemetry link non-availability, does not significantly affect the pfd values. The pfd values are primarily determined by the value of I/N. The impact on the telemetry link measured in terms of the decrease in usable range (R) for a given (P), as a function of (I/N) can be determined from equation (7), since $R^2 \propto 1/(N+I)$ for a fixed transmitter power. The decreased usable range as a function of (I/N) is shown in Figure 4. The impact on telemetry link design becomes severe for (I/N) values greater than one (0 dB) because the link must be designed to overcome interference rather than internal noise. The maximum practical value is considered to be approximately 0.5 (-3 dB) with smaller values desired.

## 3.4 Interference Allowances

Based on the factors given in Section 3.3, the following aggregate allowances appear appropriate for this case. The total "noise" is the sum of internal noise ($N_I$) plus interference from satellites ($I_S$) plus interference from terrestrial sources ($I_T$). The aggregate permissible interference from satellites and terrestrial sources are:

$$I_S = 0.25\,(N_I + I_S + I_T) \tag{11}$$

$$I_T = 0.10\,(N_I + I_S + I_T) \tag{12}$$

From this, the aggregate allowable (I/N) from satellites is 0.3846 or -4.15 dB, and from terrestrial sources is 0.1538 or -8.13 dB. Since pfd is not particularly sensitive to (P), a mid range value of (P) of 0.005 is selected for numerical evaluation which results in a $P(\Delta G)$ of 0.003611 from equation (7).

## 3.5 Minimum (S) versus Angle of Arrival ($\alpha$)

The minimum value of (S) can be determined from the minimum radius of a circle in which aircraft testing is normally accomplished (see Figure 5). (S) as a function of ($\alpha$) is determined as follows. The elevation angle of arrival is:

$$\alpha = \tan^{-1}\left[\frac{h}{d} - \frac{d}{2r}\right] \qquad \text{(radians)} \tag{13}$$

The incremental angle of arrival ($\Delta\alpha$) along the telemetry antenna pointing azimuth is:

$$\Delta\alpha = \tan^{-1}\left[\frac{h}{d-2a} - \frac{d-2a}{2r}\right] - \tan^{-1}\left[\frac{h}{d+a} - \frac{d+a}{2r}\right] \qquad d \geq a\ \text{(radians)} \tag{14a}$$

$$\Delta\alpha = \tan^{-1}\left[\frac{d+a}{h}\right] - \tan^{-1}\left[\frac{d-a}{h}\right] \qquad d < a \qquad \text{(radians)} \tag{14b}$$

The angle tangent to the azimuth ($\beta$) is:

$$\beta = 2\tan^{-1}\left[\frac{a\cos\alpha}{d}\right] \qquad \text{(radians)} \tag{15}$$

From which (S) is:

$$S = \pi/4\,(\beta)\,(\Delta\alpha) \qquad \text{(steradians)} \tag{16}$$

where:

h - aircraft altitude - 20 km
d - surface distance to aircraft (320 km maximum)
r - radius of the earth - 6376 km
a - minimum radius of flight patterns - 20 km

### 3.6 pfd Versus Angle of Arrival

#### 3.6.1 pfd Escalation Due to (S)

The permissible pfd increases with (S) which increases with angle of arrival ($\alpha$). The pfd as a function of (S) can be calculated using equation (16) in conjunction with the ($\Delta G$) versus (S) functions developed in Section 3.2 for a $P(\Delta G) = 0.003611$ which, in turn, is used in equation 10. The minimum (S) is 0.001262 steradians.

#### 3.6.2 pfd Escalation Due to Excess Margin

There will be some distance ($d_o$) between the telemetry receiving station and the airborne vehicle at which the desired availability is generally exceeded. Thus, excess margin is available which could be used to increase the allowable pfd. The value of ($d_o$) can be determined by:

$$d_o = \left[\frac{PG_a G_o}{1758\ KTBM\ f^2\ (C/N)_T}\right]^{0.5} \text{ (km)} \qquad (17)$$

| | | | | |
|---|---|---|---|---|
| where | $P$ | - | aircraft power-watts | 4 |
| | $G_a$ | - | aircraft median antenna gain | 0.2 |
| | $G_o$ | - | telemetry receiving antenna gain | 800 |
| | $M$ | - | availability margin required | 300 |
| | $f$ | - | frequency - MHz | 1500 |
| | $T$ | - | noise temperature - K° | 250 |
| | $B$ | - | bandwidth - Hz | $3 \times 10^6$ |
| | $(C/N)_T$ | - | threshold value | 32 |

The nominal values for each parameter as listed above are considered to be the most appropriate for determining ($d_o$). Solution of equation (17) with these values result in a ($d_o$) of 40 km.

The angle of arrival ($\alpha$) is determined by the distance (d) and the aircraft height (h) and is:

$$\alpha = \arcsin (h/d) \qquad (18)$$

From equation (18), ($\alpha$) as a function of (d) for values of (d) between ($d_o$) and (h) can be determined. The excess margin ($M_e$) which can be used to increase the pfd is:

$$M_e = (d_o/d)^2 \qquad (19)$$

The maximum value of (h) is assumed to be 20 km. Using these values ($M_e$) as a function of ($\alpha$) is computed. A nearly exact formulation of this function can be expressed as a pfd escalation factor ($pfd_e$) as follows:

$$pfd_e = 1 \quad ; 0 \le \alpha \le 30° \qquad (20a)$$

$$pfd_e = 1 + 0.066\,(\alpha - 30) \quad ; 30° < \alpha \le 62.5° \qquad (20b)$$

$$pfd_e = 4 \sin^2\alpha \quad ; 62.5° < \alpha \le 90° \qquad (20c)$$

### 3.7 Multiple Entries

When the value of (S) is very small, side and back lobe interference levels from similar satellites in the (GSO) will be insignificant as compared to the main lobe level. As (S) increases, the side and back lobe contributions become statistically significant and are accounted for on a per-satellite basis in paragraph 3.1. Therefore, multiple entries are primarily related to the number of geostationary satellites within the limited steradian coverage of the telemetry antenna (S).

First, it is assumed that an area (S') is circular and that its diameter ($\delta$) is aligned with the GSO, and second, it is assumed that there are (N) satellites equally spaced by an angle ($\Delta$), each producing equal pfds at the telemetry antenna.

When ($\delta$) is equal to ($\Delta$), two entries are possible but the probability is near 0. When ($\delta$) is equal to ($2\Delta$), the probability of two entries is near 1, while probability of three entries is near 0, and so forth. Thus, for a probability of about 0.5:

$\delta = (N-0.5)\Delta$; $\delta$ and $\Delta$ in degrees (21)

The area/ (S') is:

$S' = (\pi/4)\,\delta^2$ (steradians); $\delta$- radians (22)

From this model, (N) is closely approximated by:

$N = 70(S')^{0.5}/\,\Delta;\ \Delta^2/4900 \leq S \leq 1.938$ (23)

Since $N \geq 1$, $S' \geq \Delta^2/4900$, and since the "maximum" minimum value of (S) from paragraph 6.3 is 1.938, (N) in equation (36) is limited to this range. Thus, (N) is limited to the range; $1 \leq N \leq (90/\Delta + 0.5)$.

The single entry escalation ($pfd_{es}$) is related to the aggregate ($pfd_{ea}$) by

$pfd_{es} = pfd_{ea}/N$ (24)

## 4.0 COORDINATION THRESHOLD

From the preceding analyses, values of single entry pfds may be developed. When the pfd from a satellite is less than the single entry value, coordination would not be required. The pfd single entry values developed in the following sections are proposed as applicable for Aeronautical Mobile Telemetry systems. Telemetry systems parameter values are as follows:

T - Receiving Station Noise Temperature - 250°K
B - Referenced Bandwidth - 4 kHz
$\lambda$ - Wavelength - 0.2 meters
I/N - Interference/Noise - 0.3846
P($\Delta$G) - Probability of Differential Gain - 0.003611

Using these values in conjunction with the ($\Delta$G) versus (S) function, the excess margin and multiple entry factor for a ($\Delta$) of 45°, results in the function shown in Figure 6. As also shown in Figure 6, the pfd versus angle of arrival is closely approximated by:

| | | |
|---|---|---|
| $pfd \leq -181.0$ | ; $0 \leq \alpha \leq 4°$ (dBW/m$^2$/4 kHz) | (25a) |
| $pfd \leq -193.0 + 20 \log \alpha$ | ; $4° \leq \alpha \leq 20°$ (dBW/m$^2$/4 kHz) | (25b) |
| $pfd \leq -213.3 + 35.6.1 \log \alpha$ | ; $20° \leq \alpha \leq 60°$ (dBW/m$^2$/4 kHz) | (25c) |
| $pfd \leq -150$ | ; $60° \leq \alpha \leq 90°$ (dBW/m$^2$/4 kHz) | (25d) |

## 5.0 COORDINATION CONSIDERATIONS FOR SATELLITE INTERFERENCE TO AERONAUTICAL TELEMETRY SYSTEMS

### 5.1 General

When the coordination thresholds are exceeded, coordination with the affected Aeronautical Telemetry systems would be required. There are a number of factors and techniques by which successful coordination may be achieved. Some of the applicable factors and techniques that apply to Aeronautical Telemetry systems are addressed in the following paragraphs.

### 5.2 Telemetry Carrier Bandwidth

Power flux densities are commonly expressed in a 4 kHz bandwidth at these frequencies. When the interfered-with carrier bandwidth is much larger than 4 kHz, the assumption that the highest pfd per 4 kHz exists over the interfered-with carrier bandwidth may over estimate the actual level of interference. Thus, expressing a pfd in the minimum interfered-with bandwidth that is most sensitive to interference more accurately represents the actual situation.

The minimum bandwidth most sensitive to interference is represented by an FSK carrier with a data rate of approximately 400 kb/s. Thus, the most sensitive portions of the carrier spectrum are approximately 400 kHz, while the total RF spectrum required is nearly 1 MHz. Thus, a pfd expressed in $dBW/m^2/400$ kHz is more appropriate.

### 5.3 Modulations

There are several types of modulations used by Aeronautical Telemetry systems, including both analog and digital, with a trend toward becoming all digital. The analyses in the preceding sections have not addressed the interference effects for various combinations of interfering and interfered-with modulations. When there are a number of interfered-with modulations involved, it is generally desirable that the interfering signal appear as broadband noise. However, certain combinations of modulations could result in interference effects that are less than broadband noise.

However, the coordination thresholds are considered valid for all types of interfering modulations, noting that the Broadcasting Service (sound) is limited to digital systems.

### 5.4 Polarizations

The aircraft antenna by itself is generally linear polarized, but the polarization leaving the aircraft will generally be elliptical with varying ellipticities and spatial orientation. As noted in Section 2.1, telemetry receiving antennas use RHC, LHC, and linear polarization. For telemetry sites where all three of these polarizations are not used, some polarization isolation may be achieved. Some sites use both RHC and LHC with diversity combining. This results in a 3 dB polarization isolation from any single polarization interfering signal.

### 5.5 Frequency Avoidance

In the case of isolated telemetry site (no overlapping air space with any other site) with a relatively light testing schedule, it may be possible to avoid the use of portions of the 1 452-1 525 MHz band. This could allow BSS(S) or MSS operations with pfds in excess of the values developed herein for co-frequency use. In the case where many overlaps occur and simultaneous testing occurs, frequency coordination between telemetry sites on a continuous basis is necessary and frequency avoidance will generally not be possible or practical.

### 5.6 Telemetry Site Specific Parameters

For telemetry sites that have parameter values different than those used for the development of coordination thresholds, acceptable pfds may be computed using the methods and equations used in the development of the coordination thresholds. These parameters include $P(\Delta G)$, (S), (d), (h), (P), (I/N), (T), etc., as defined in the preceding analyses.

## 5.7 Satellite Antenna Discrimination

When the telemetry sites are outside the coverage area of the satellite, satellite antenna discrimination is a very important factor in determining the need-to-coordinate as well as in coordination.

## 5.8 The Conjunction Case

This is the case where the main lobe of the telemetry receiving antenna can be pointed at a geostationary satellite. For this case, interference analyses need to address each telemetry receiving site. Referring to Figure 6, it is noted that the pfd for low angles of arrival are based on the on-axis gain ($G_0$) of the antenna. The pfd for values of ($G_0$) less than 33.3 dB are computed by equation (8) with the parameter values in Section 4. Using these values:

$$\text{pfd} \leq -146.7 - G_0 \text{ (dB)} \qquad (\text{dBW/m}^2/4 \text{ kHz}) \qquad (26)$$

for $20 \leq G_0 \leq 33.3$.

The value of pfd computed by equation (26) extends to the intersection with the escalation function of Figure 6.

Three parameters are needed to use this figure: (1) the locations of the telemetry receiving sites, (2) the maximum antenna gain at each site, and (3) the geostationary location. This first step is relatively simple and may eliminate a number of sites from further consideration.

For those cases requiring further consideration, there may be some cases where the telemetry antenna does not have a conjunction with the geostationary satellite at low angles of arrival but does have a conjunction at higher angles of arrival. This could occur when the azimuth limits for testing at long ranges are such that conjunctions would not occur for low angles of arrival, but can occur at higher angles because (S) increases with ($\alpha$). The minimum pfd value for this case is the value in Figure 6 at the angle ($\alpha$) where conjunctions first occur.

## 5.9 The No Conjunction Case

It is possible that in coordination, there are telemetry sites where the antennas can avoid a geostationary satellite by some value of solid angle which is acceptable for those sites' operations.

A first order approximation for the escalation of the aggregate pfd can be obtained from equation (1). One particular case is of interest, i.e., the case of the telemetry antenna main lobe avoidance (to the first side lobe level). This avoidance angle is approximately 1.5° for a 10m antenna and approximately 6° for a 2.44m antenna. For low elevation angles, the incremental pfd ($\Delta$ pfd) is the ratio of ($G_0$) divided by the first side lobe level. While the value of ($\Delta$ pfd) increases with decreasing ($G_0$), the avoidance angle of the telemetry antenna increases with decreasing ($G_0$). Main lobe avoidance, where possible, may significantly increase the allowable pfd at low angles of arrival but more detailed analyses would be needed in coordination.

## 6.0 AERONAUTICAL MOBILE TELEMETRY OPERATION IN THE UNITED STATES

Appendix 1 provides information on telemetry receiving stations in the United States.

(1) CCIR Report to WARC-92

## APPENDIX 1

## AERONAUTICAL TELEMETRY RECEIVING STATION LOCATIONS IN THE UNITED STATES

Table A-1 shows the approximate location of telemetry receiving stations at many of the major test ranges. The list also contains the number of antennas and on-axis gains. For the large test ranges, some of the station locations may be ±1° from the indicated locations. Table A-2 shows a large portion of the additional telemetry receiving station locations. These stations have a small number of antennas (many have only one). The on-axis gains are between 20 dBi and 30 dBi. These locations are shown graphically in Figure A-1.

In the case of isolated telemetry sites (no overlapping air space with any other site) with a relatively light testing schedule, it may be possible to avoid the use of portions of the 1 452 - 1 525 MHz band. In the usual case, where many overlaps occur and simultaneous testing occurs, frequency coordination between telemetry sites on a continuous basis is necessary and frequency avoidance will generally not be possible or practical.

Tables A-1 and A-2, though incomplete, indicate the extensive use of the 1 452 - 1 525 MHz band in the United States for mobile aeronautical telemetry operations. This use needs to be taken into account in the development of any sharing criteria with respect to the broadcasting satellite (sound), broadcasting (sound), and the mobile-satellite services.

**Table A-1. Telemetry Receiving Stations on Major Test Ranges**

| United States | Coordinates | | Number and Gain of Antenna | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| State | Long. | Lat. | No. | dBi | No. | dBi | No. | dBi | dBi (max.) | No. Total |
| Puerto Rico | 66.7 W | 18.3 N | 1 | 28 | 7 | 30 | 1 | 34 | 34 | 9 |
| New York | 72.8 W | 40.9 N | 1 | 40 | | | | | 40 | 1 |
| Virginia | 76.0 W | 36.9 N | 2 | 30 | | | | | 30 | 2 |
| Maryland | 76.4 W | 38.3 N | 4 | 29 | 2 | 30 | 1 | 32 | 32 | 7 |
| Florida | 85.8 W | 30.2 N | 2 | 28 | | | | | 28 | 2 |
| Florida | 86.5 W | 30.5 N | 1 | 28 | 8 | 34 | | | 34 | 9 |
| Missouri | 90.4 W | 38.8 N | 1 | 22 | 1 | 29 | | | 29 | 2 |
| New Mexico | 106.4 W | 33.2 N | 7 | 28 | 1 | 36 | 2 | 38 | 38 | 10 |
| Utah | 113.2 W | 41.0 N | 1 | 21 | 2 | 28 | 1 | 34 | 34 | 4 |
| Arizona | 114.4 W | 32.9 N | 4 | 26 | | | | | 26 | 4 |
| Nevada | 116.8 W | 37.8 N | 5 | 28 | 1 | 33 | | | 33 | 6 |
| California | 117.5 W | 35.8 N | 3 | 25 | 6 | 26 | 2 | 30 | 30 | 11 |
| California | 117.9 W | 34.9 N | 10 | 28 | 1 | 33 | | | 33 | 11 |
| California | 119.1 W | 34.1 N | 1 | 27 | 2 | 37 | 4 | 40 | 40 | 7 |
| California | 119.5 W | 33.2N | 4 | 28 | 2 | 37 | 3 | 39 | 39 | 9 |
| California | 120.4 W | 34.6 N | 1 | 28 | 1 | 39 | 1 | 41 | 41 | 3 |
| California | 122.5 W | 37.5 N | 2 | 41 | | | | | 41 | 2 |
| Hawaii | 159.7 W | 22.0 N | 3 | 28 | 3 | 39 | | | 39 | 6 |
| TOTAL: 18 | | | TOTAL ANTENNAS: 105 | | | | | | | |

Table A-2. Additional Telemetry Receiving Station Locations

| United States | Coordinates | | United States | Coordinates | | United States | Coordinates | |
|---|---|---|---|---|---|---|---|---|
| State | Long. | Lat. | State | Long. | Lat. | State | Long. | Lat. |
| Connecticut | 73.1 W | 41.2 N | Kansas | 97.3 W | 37.6 N | California | 117.2 W | 32.8 N |
| Pennsylvania | 75.3 W | 39.9 N | Texas | 97.5 W | 32.8 N | California | 117.3 W | 33.1 N |
| Delaware | 75.6 W | 39.7 N | Texas | 97.8 W | 32.7 N | California | 118.2 W | 35.1 N |
| North Carolina | 79.0 W | 35.1 N | Colorado | 105.9 W | 37.4 N | California | 118.2 W | 34.4 N |
| Florida | 80.2 W | 27.2 N | New Mexico | 106.1 W | 32.9 N | California | 118.2 W | 33.8 N |
| Florida | 80.3 W | 26.9 N | Texas | 106.2 W | 32.1 N | California | 118.3 W | 33.9 N |
| Ohio | 84.0 W | 39.8 N | Colorado | 106.3 W | 39.2 N | California | 118.4 W | 34.0 N |
| Georgia | 84.5 W | 33.9 N | Montana | 106.5 W | 48.4 N | California | 118.4 W | 37.4 N |
| Michigan | 84.9 W | 44.6 N | Arizona | 110.4 W | 31.6 N | California | 120.1 W | 34.6 N |
| Alabama | 85.5 W | 31.4 N | Arizona | 110.7 W | 33.5 N | California | 120.2 W | 39.2 N |
| Minnesota | 93.5 W | 48.5 N | Utah | 113.4 W | 40.2 N | California | 121.2 W | 37.4 N |
| Minnesota | 93.5 W | 45.5 N | Arizona | 114.6 W | 32.5 N | Washington | 122.3 W | 47.5 N |
| Louisiana | 93.7 W | 32.5 N | Nevada | 115.1 W | 39.3 N | | | |
| Oklahoma | 95.9 W | 36.2 N | Nevada | 115.3 W | 36.2 N | | | |

Figure 1

Measured data on 2.44 metre diameter antennas

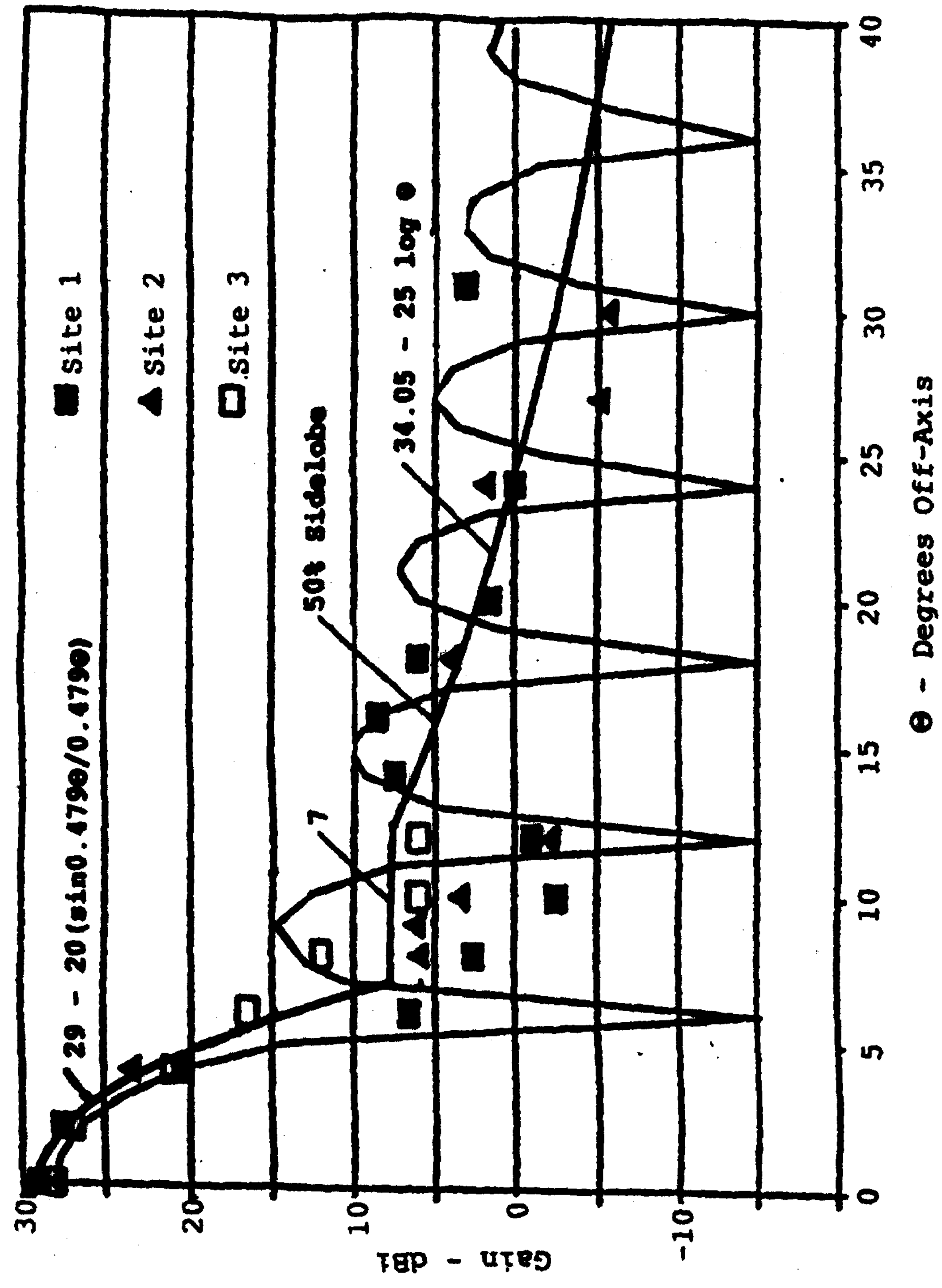


Figure 2

**Airborne telemetry transmitting antenna gains ($G_1$)**

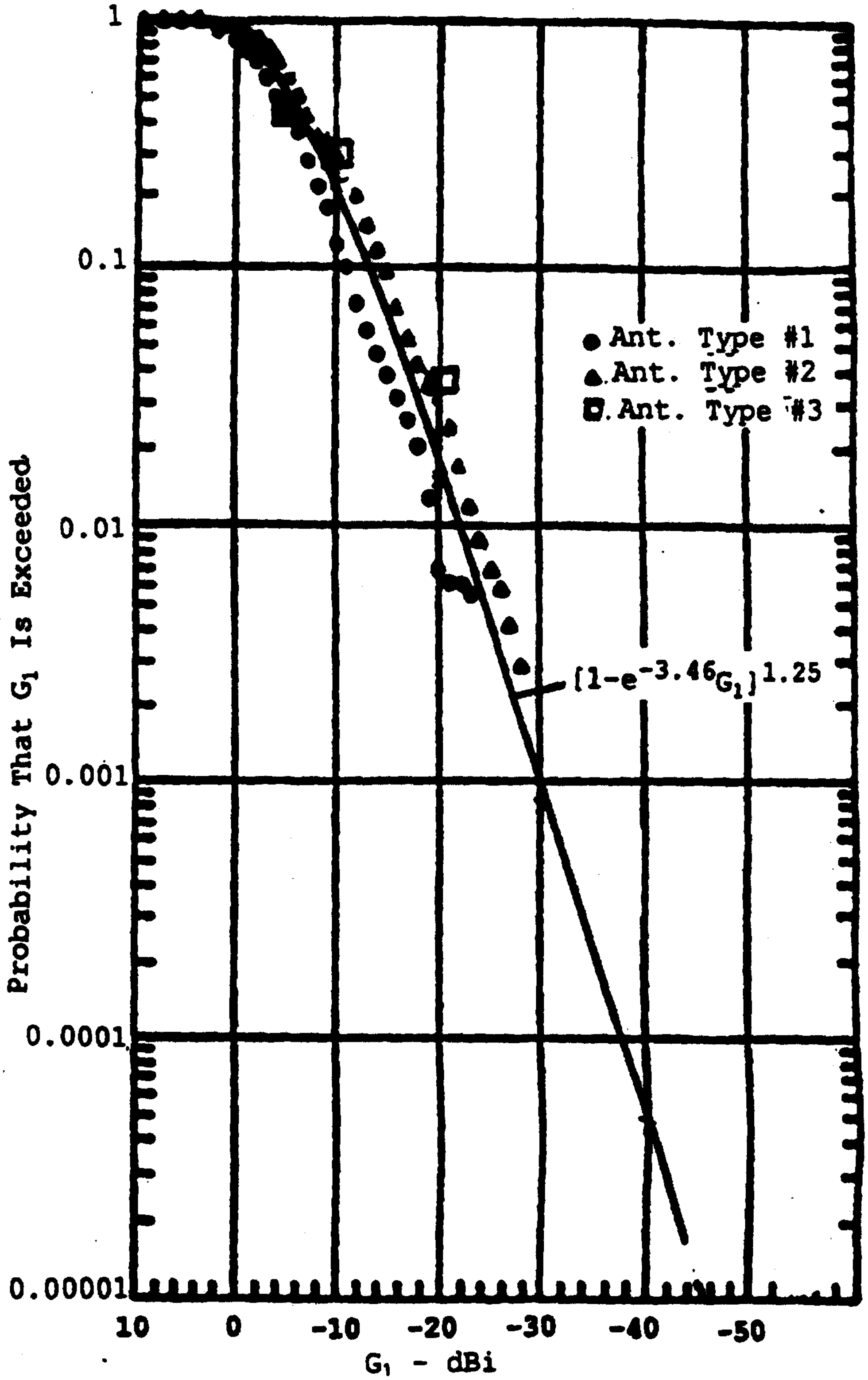


Figure 3

Telemetry receiving antenna gain probability ($G_2$)

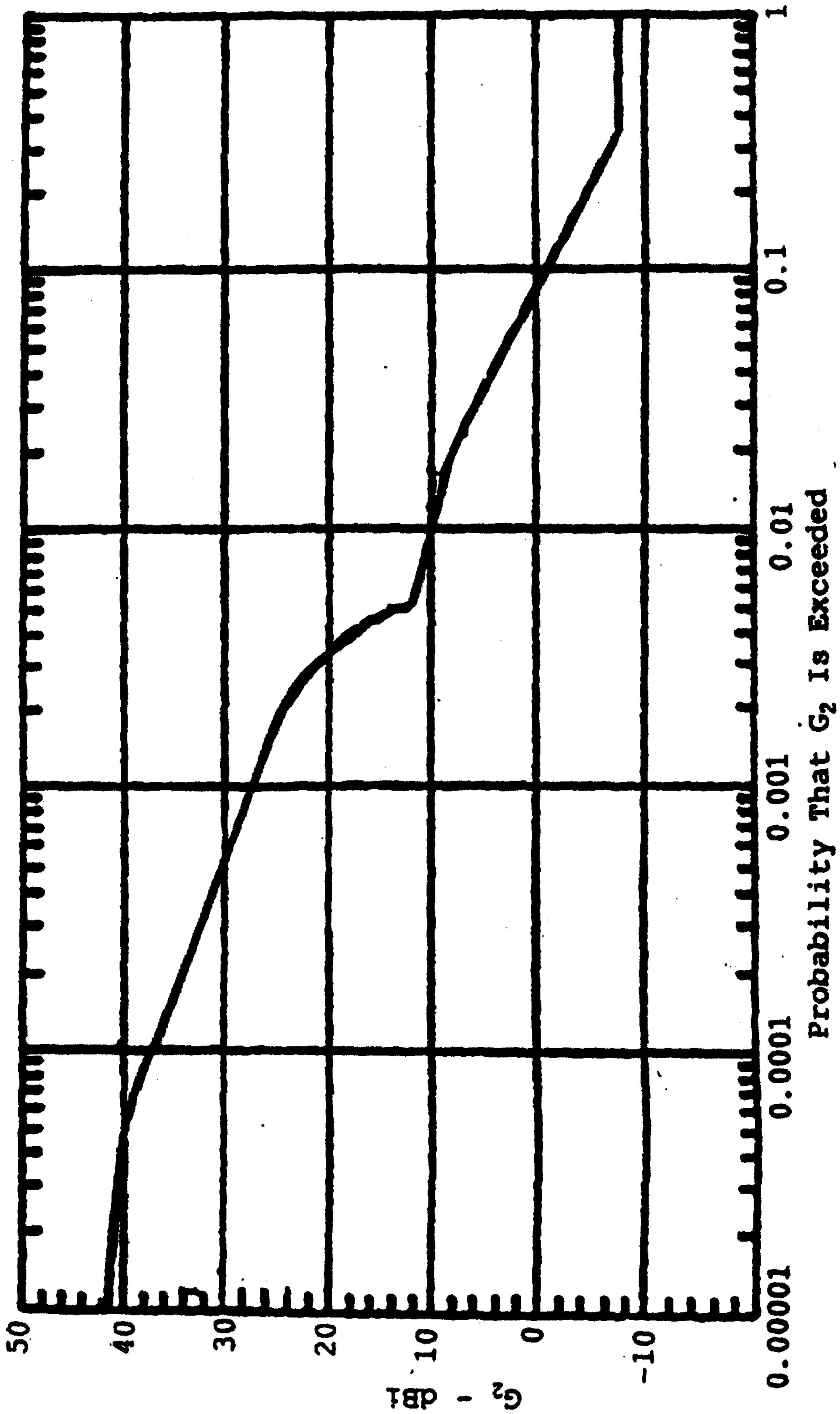


Figure 4

**Decrease in usable range versus I/N**

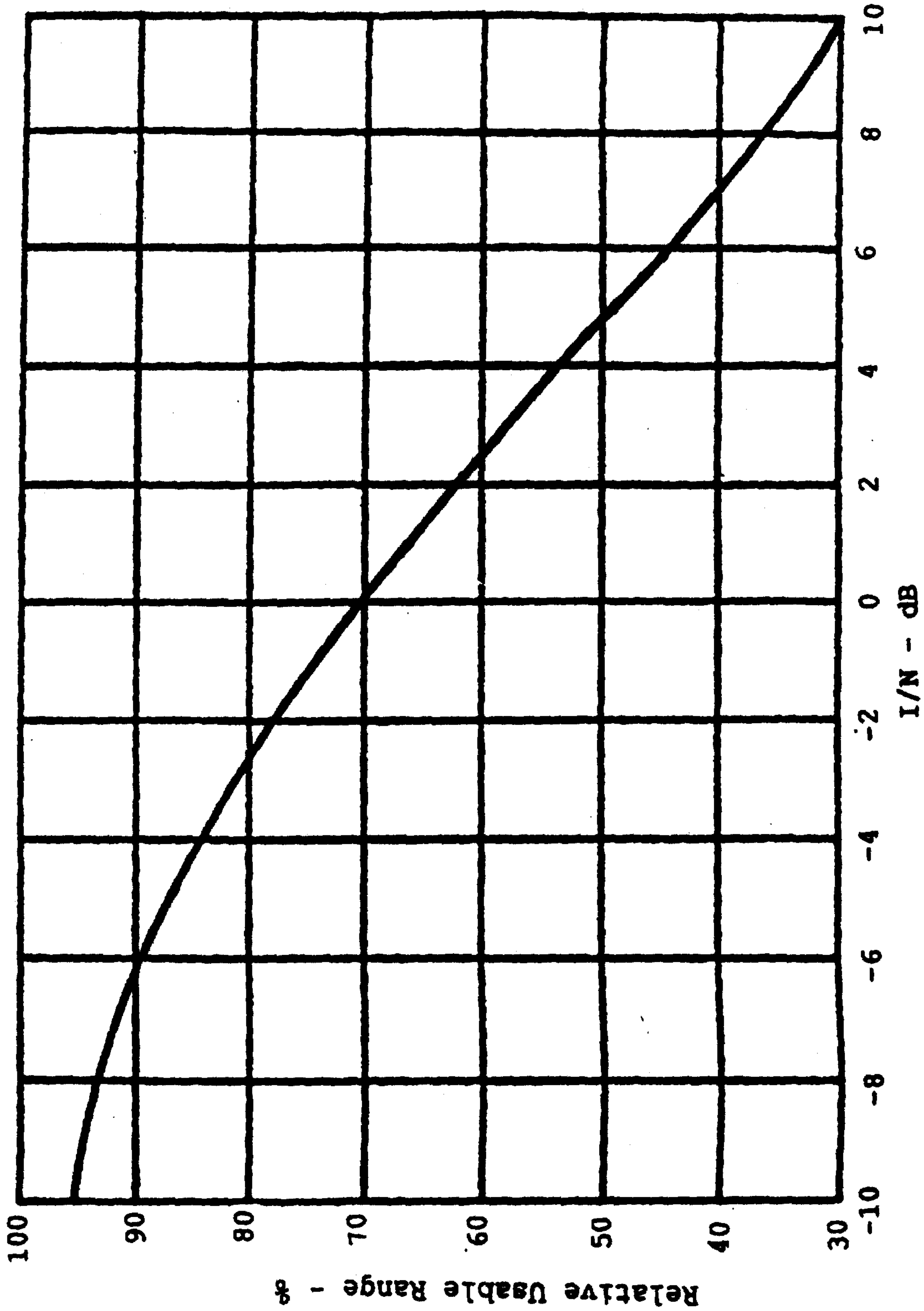


Figure 5

**Geometry for "S" computations for geostationary satellites**

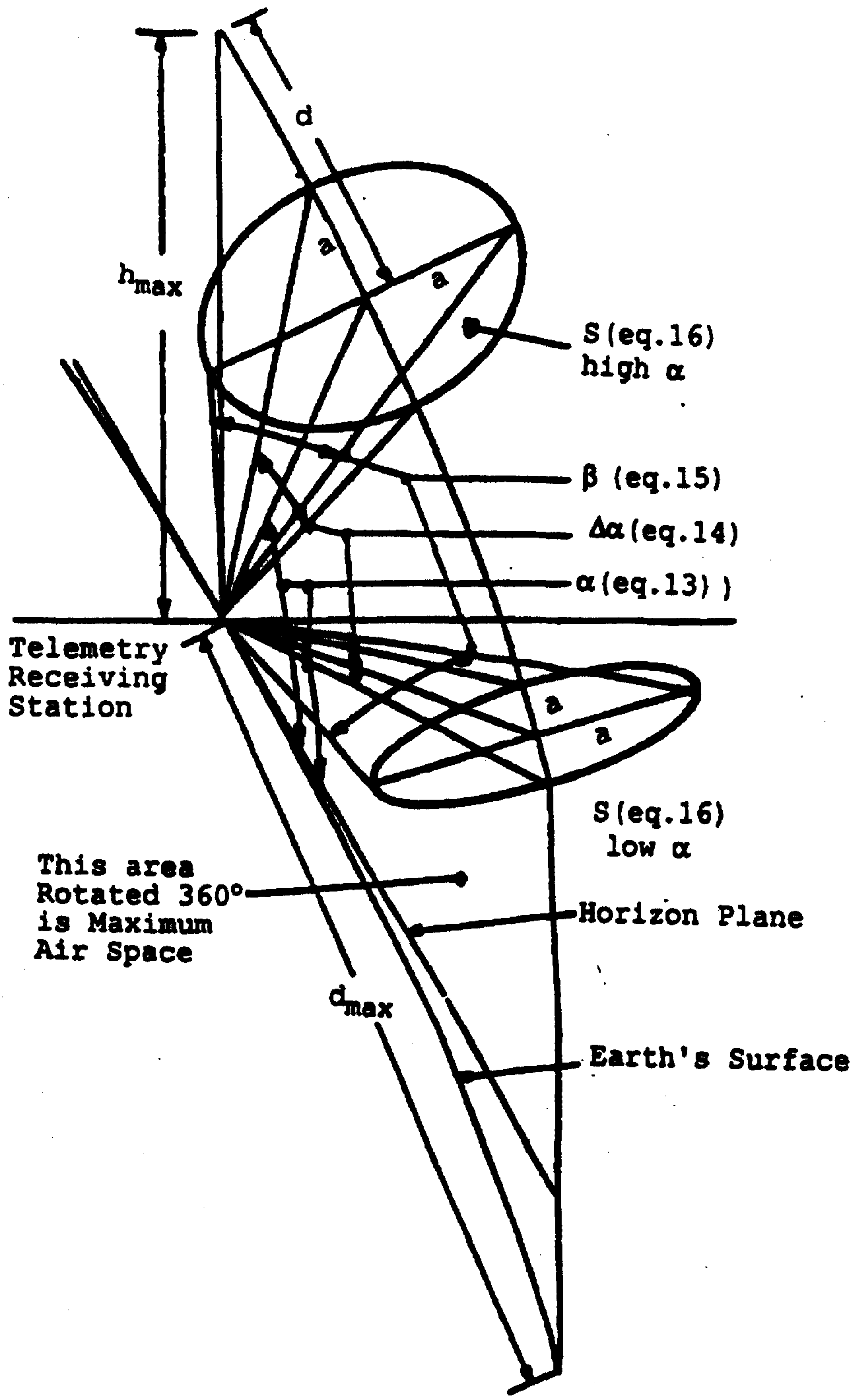
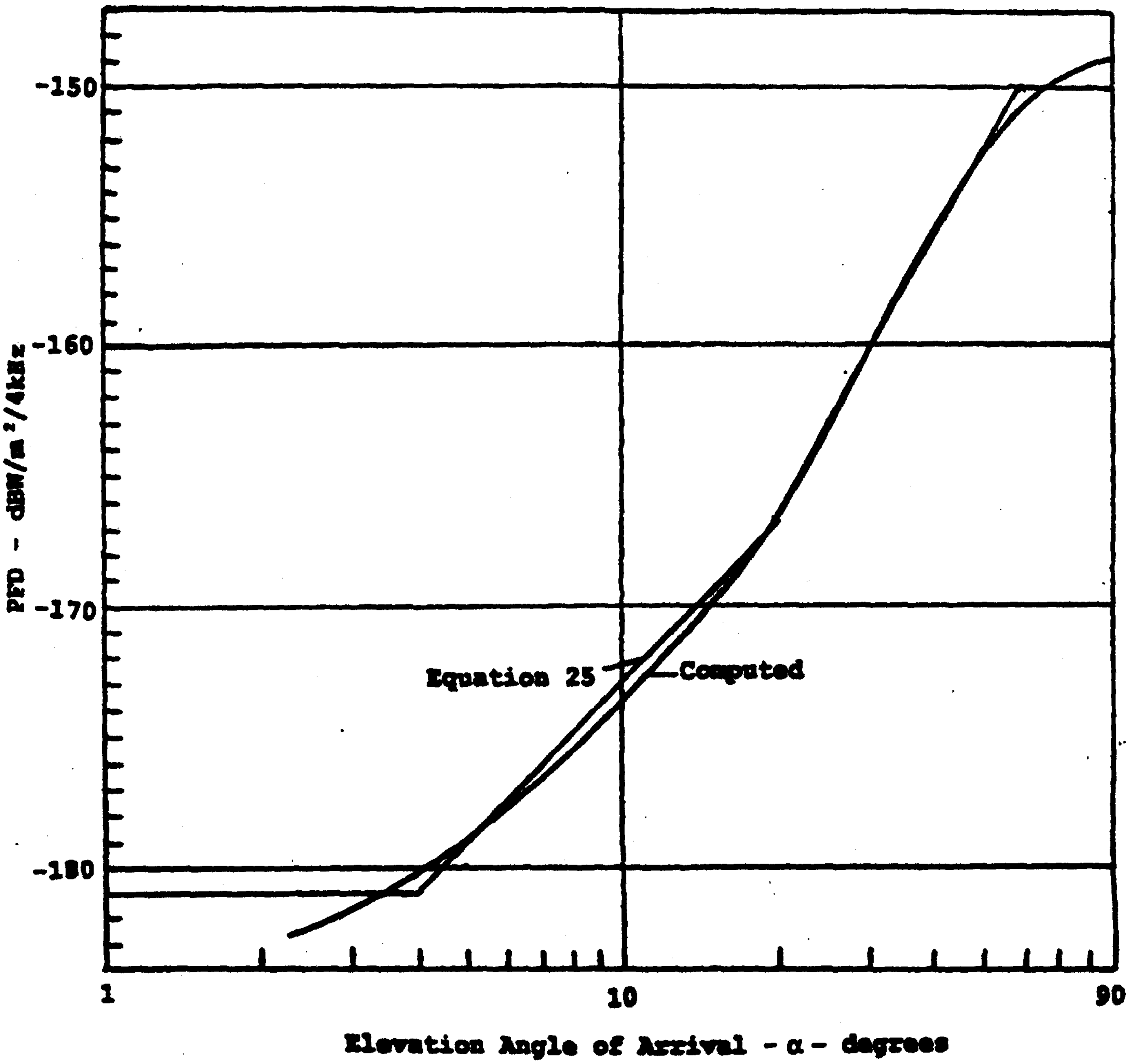


Figure 6

SINGLE ENTRY THRESHOLDS FOR AERONAUTICAL TELEMETRY RECEIVING STATIONS DUE TO INTERFERENCE FROM GEOSTATIONARY SATELLITES



# Figure A-1

**United States aeronautical telemetry receiving station locations**